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AUTHOR McConkie, George W.; Zola, David
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ABSTRACT

Results from studies of language identification in noise and of word identification from tachistoscopic presentation clearly indicate that contextual information can be used to facilitate word identification under inadequate stimulus conditions. But these results do not provide strong evidence that such an interaction is occurring during normal reading. Other forms of evidence using tasks more similar to reading (proofreading errors and errors in reading aloud) produce the same dilemma. Three aspects of perception have been identified that might be affected by contextual information: where the eyes are sent, the visual region attended to, and the visual information within that region that is used for reading. But studies that have investigated perception during reading are not definitive on these issues; and there currently appears to be no clear evidence that the contextual information environment exerts control over what visual information is used in reading, that is, over the functional stimulus. In fact, subjects appear to be responding to considerable visual detail of words that are almost completely constrained by their prior context. From present evidence, then, it seems quite possible that contextual facilitation is not achieved by reducing the amount of visual information a reader acquires from individual words. (RL)

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CENTER FOR THE STUDY OF READING

Technical Report No. 194

LANGUAGE CONSTRAINTS AND THE FUNCTIONAL STIMULUS IN READING

George W. McConkie and David Zola
University of Illinois at Urbana-Champaign

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University of Illinois
at Urbana-Champaign
51 Gerty Drive
Champaign, Illinois 61820

Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

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Abstract

This report evaluates evidence that language constraints influence the functional stimulus in reading. Three possible types of influences are discussed: influences on where the eyes are sent, on what region of text is attended during a fixation, and on what aspects of the text within this region are attended and used for reading. While there is evidence for contextual facilitation in reading, it has not yet been shown that this is due to changes in what aspects of the text stimulus are being perceived.

Language Constraints and the Functional Stimulus in Reading

In the struggle to understand how perception takes place in a particular task such as reading, two primary questions can be asked. First, what is serving as the functional stimulus for the perception, and second, what is the nature of the perceptual activities by which the use of this stimulus information yields its effects? The first of these questions is the most directly empirical in nature. If empirical data can specify the functional stimulus for perception under certain conditions, then the task of understanding the mental activities of perception under those conditions can be addressed more profitably. Without good evidence about what is actually serving as the stimulus, further theorizing about perceptual activities is on somewhat shaky ground, being based on unsupported assumptions concerning what aspects of the visual information are actually being used.

The purpose of the present paper is to consider the nature of the functional stimulus in reading; that is, what aspects of the text stimulus are being attended to or used for reading. The discussion of this topic requires that a distinction be made between visual information and contextual information. This is a common distinction in the literature, but the boundary between the two categories varies depending on the author's purposes and theoretical inclination. For the present paper, we will adopt a more extreme position than is usually taken. We use the term visual information to refer only to the visual characteristics of the text that are available during a particular fixation during reading. Contextual

information refers to all other information the reader has up to that point which places constraints on what the presently available visual information might be. This contextual information might have been gained from earlier portions of the text or simply be available from prior knowledge of the language, the nature of passages, the author's writing style, the topic being discussed, and so forth.

The particular question we wish to address is whether contextual information produces changes in what visual information is acquired and used for reading during a fixation; that is, whether contextual information influences the functional stimulus. This is treated as an empirical question. We consider to some degree the evidence from tasks that do not involve normal reading, as well as studies of reading itself. We evaluate the evidence for the frequently made claim that contextual information influences what visual information is attended to and used during reading.

The assumption that such influences exist has been prominent in the reading field for decades. The primary concern has been with the way contextual information influences visual processing. Different theorists have provided different possible explanations (for example, see Goodman, 1967; Hochberg, 1970; Neisser, 1967; Rumelhart, 1977). This assumed use of contextual information to control what serves as the functional stimulus in reading is often spoken of as an example of higher-level processes influencing lower-level processes.

Studies Involving Tasks Other Than Skilled Silent Reading

There have been many studies which have demonstrated contextual facilitation of perception in tasks using language-based stimuli (e.g., letters, words and sentences). Two types of such research deal with perception of language in noise and perception of printed language presented tachistoscopically.

Perceiving Language in Noise

Most of this research has been done with auditory presentation of language. Miller, Heise, and Lichten (1951), for instance, asked subjects to identify words presented in noise and found that the amount of information necessary for word identification was a function of the number of possible alternative words that could occupy that location in the language. As the range of alternatives decreased, more noise could be tolerated; that is, less information from the word itself was needed for correct identification to occur. For example, the word trees was readily identified in the sentence Apples grow on trees, even when the noise level presented with that word was very high. The authors interpreted this result as indicating that the contextual environment in which a word is presented allows the listener to limit the range of alternatives, thus facilitating the perception of the word, possibly by allowing its identification with less stimulus information. Miller and Isard (1963) further extended these results by demonstrating that both semantic and syntactic information can produce such a context effect. Thus, the context provides multiple sources of information that can limit potential word alternatives. This work made

it clear that under impoverished stimulus conditions, listeners can and do use contextual information from their conceptual and linguistic knowledge to interpret what they hear. A related finding using visual noise in reading was reported by Sawyer (1971). She showed that grammatical constraints influenced subjects' ability to read blurred parts of sentences.

Perceiving Briefly Presented Words

Another line of research demonstrating contextual facilitation of word recognition has involved subjects in identifying words presented very briefly, using either a tachistoscope or computer display to control the length of the stimulus presentation. O'Neil (1953) and Rouse and Verinis (1962) showed that preceding a to-be-identified target word with a context word, which is associatively related to it, made it possible to identify the target word with shorter presentations. Samuels (1969) made this same demonstration and also showed the influence of word familiarity using semantically related adjective-noun pairs. Tulving and Gold (1963) extended this finding to more normal language materials. They found that preceding the presentation of the target word with a sentence, which the target word would then complete, reduced the presentation time necessary for accurate identification of that word. Tulving, Mandler, and Baumal (1964) suggested that in this task, sources of stimulus information from the word are interchangeable with sources of contextual information. Morton (1964) took this logic one step further, claiming that a reader utilizes some available contextual information to predict the target word, thus allowing the reader to use fewer visual cues to perceive the word. Jacobson (1973) demonstrated

the same facilitation in oral reading and visual masking tasks, and even demonstrated an effect using cross-modal presentation (context presented aurally, target word, visually).

In a manner similar to the research on the perception of language in noise, these and many other studies have shown that under impoverished stimulus conditions a person uses contextual information to aid word identification, and that with greater contextual constraint a target word can be identified with less stimulus information.

Generalizing to Reading

It is but a small step from this body of research to suggest that in normal reading people may be able to "trade off" these sources of information in their perception of text. When the reader is about to encounter a given word, the contextual information is already in mind, so it seems quite reasonable to believe that efficiency might result from making full use of this information in the identification of the next word, thus reducing the amount of visual information that is required from the word itself. There are two reasons why this might be seen as contributing to efficiency in reading. First, a reduction in the amount of visual analysis of the word may be a means of reducing the number of mental operations needed in its identification, thus providing a time savings. This assumes, of course, that putting available contextual information to use for word identification purposes is cognitively easier or faster than acquiring and using additional visual information. Second, using the mind-computer analogy, which is so common in cognitive psychology today, we might suppose

that the slowest aspect of mental computing is the I/O (input/output) activity. Thus, operating on information that is already in the mind may be substantially faster than taking in new information. If this were the case (as it typically is with computers), then efficiency could be gained by utilizing existing information (contextual information) as fully as possible and depending minimally on the acquisition of information from visual stimuli.

Several mechanisms have been proposed in the literature by which this sort of efficiency in reading might be achieved, each attempting to explain how the reader succeeds in depending more heavily on contextual information in order to reduce the amount of visual information that must be extracted from the text itself. Neisser (1967) and Levin and Kaplan (1970) suggested an analysis-by-synthesis approach (also see a description by Wanat, 1971; and a recent summarization by Haber, 1978) patterned after work on the understanding of oral language by Halle and Stevens (1967). Goodman (1967) proposed a more extreme version in which readers were described as making specific guesses about the words yet to be visually encountered, with minimal visual information then being used simply to confirm or disconfirm these guesses. McConkie and Rayner (1976) suggested that such guesses may not be necessary and that the reader simply may take in information from a word over time as needed. Such visual information was thought to be used in combination with contextual information as it was acquired, in something like a discrimination net, seeking a unique reading of the word. Once a decision was made, the acquisition of new visual information could be

terminated. Brown (1970) suggested that the acquisition of visual information from a word may occur in a fixed sequence, which he called a "noticing order." More gross visual aspects are acquired first, for example, word length, general overall word shape, and perhaps initial and terminal letters. Finer details indicating internal letters would only be acquired later. Again the process of acquiring visual information could be discontinued once the word was identified, thus producing the desired efficiency in visual processing.

Such proposals depict the reader as not wasting processing time on the analysis of visual detail that is not needed for discriminating between possible alternative words permitted by the context. This is very much a "top-down" approach to thinking about perception during reading. Perception is conceived of as involving the judicious positioning of the eyes based on one's knowledge of what is likely to be present next in the text, with perhaps some gross visual cues from the visual periphery to help in this decision (Hochberg, 1970), and as involving an extreme attentional selectivity during fixations, that is, choosing to attend to those aspects of a word which are likely to be useful in making the decisions involved in efficient identification or confirmation. Under high-language-constraint conditions, one would expect that much of the visual detail of the text would never be cognitively encountered by the reader since that detail is not needed under such conditions. Either the eyes would skip over it completely (that is, fixations would be far enough apart that this particular visual pattern would never occupy a retinal location that permits

detailed resolution), or it would be given only cursory visual analysis (that is, although it may occupy a retinal region where the detail could be resolved, in fact the reader effectively ignores it).

It is important to note that the research basis for this position largely involved perception under impoverished stimulus conditions. When people are attempting to identify words from insufficient visual information, they are able to use information from the context to help. In such a task it seems likely that subjects, if they are to perform adequately, are forced to adopt a strategy that maximizes the use of nonvisual information. Subjects could use contextual information to narrow the range of possibilities, or use it to aid in determining which aspects of the stimulus to attend to. The sophistication of the visual system in accomplishing this task is attested to by the conscious experience one has in a tachistoscopic task. With no contextual information, a 40 msec. presentation followed by a mask can leave one with the feeling of having simply seen a smudge, or perhaps a letter or two. An appropriate context produces a drastic improvement of clarity. There is a feeling of having clearly seen the word, and there is a remarkable improvement in the accuracy of the report.

In the normal reading situation, however, people are seldom faced with inadequate stimuli. The text is typically clear and is constantly present for observation. Thus it is quite possible that the types of strategies that are so useful in the impoverished stimulus situation are unnecessary and not employed during normal reading. Is there any evidence that certain

aspects of the available visual information are ignored during the reading of clear, persistent text?

There are two lines of research that suggest that certain stimulus information is not utilized in making word identification decisions: errors in oral reading, and proofreaders' errors.

Oral Reading Errors

As people read orally, they occasionally make errors, sometimes inserting words that are not in the original text, sometimes leaving out words, and sometimes replacing text words with other words. These replacements have been of particular interest and have been dubbed "miscues" by Goodman (1969). Miscues are taken as an indication of which aspects of the text were actually used in the word identification process and, hence, as a rather direct indication of the detailed aspects of the reader's perceptual and linguistic processing. Many of these types of errors are contextually appropriate; that is, given the language up to that point, the miscue tends to be an appropriate continuation of the sentence (though it may not combine properly with text not yet encountered, of course). This observation is taken as evidence that contextual information was used in identifying the words. Such errors often preserve aspects of the original text word, such as initial letters, length, and so forth. This fact is taken as evidence that such aspects of the original text were also used in word identification. Those aspects of the printed word that do not jibe with the spoken word are assumed to indicate aspects of the original stimulus that were not used in the identification process. The very

existence of such errors is taken as evidence that certain words or parts of words are not perceived by readers.

It should be noted that most of this miscue analysis has been done with children who are learning to read. It seems quite possible that developing readers have difficulty using all the available information at any given moment in order both to achieve an understanding of the message of the text and produce a spoken version of it that will be acceptable to the listener. In the task of reading aloud, it is a requirement that one say something. Thus, even when the person may be having difficulty, it is still necessary to produce the most appropriate spoken language possible, and the reader does this. To some degree, the miscues indicate the basis on which the language was generated. Interestingly, readers, and particularly older readers, occasionally produce a synonym for a word that is actually in the text. This would suggest that the meaning of the text was perceived and that a word then was chosen for production based strictly on the meaning. It seems likely that the visual characteristics of the word were used in obtaining the meaning (unless, of course, it was strictly guessed from the context), and then not used in selecting a word for production. This points up the problem in the task of reading aloud of trying to distinguish between what information was used in understanding language and what information seems to have been used in selecting the words to say (see Allport, 1979, for a further discussion of the distinction between the use of information for understanding vs. production). It is not known how accurately the miscue data indicate what visual information the reader actually attended

to, or even what information might have been used by the same person for identifying the word had it not been for the requirement of producing an oral response. Thus, although the existence of miscues in oral reading can be explained by a reader's failure to attend to some visual information, such an explanation is not required by it.

Proofreaders' Errors

Another source of evidence that parts of the text stimulus are ignored during reading comes from proofreaders' errors. It is often difficult to find certain spelling and typographic errors in text. However, once they are seen, the errors are quite obvious. At the same time, it must be noted that other errors are not only readily perceptible but seem to "jump out" at the reader under normal reading conditions. A related observation comes from studies (e.g., Frith, 1979; Smith & Groat, 1979) where subjects are asked to mark all instances of a certain letter in a passage. Certain letters are more likely to be missed in some locations in the text than in others. One reasonable explanation for these phenomena is that during reading much visual information is not needed and hence is not attended to, and that these reading habits carry over into other tasks involving textual materials. Thus, errors and letters are missed because they lie at locations that are not visually analyzed during reading. In fact, with this assumption, such tasks can be used to identify which parts of the text tend to be skipped over during reading.

Again it must be recognized that such an explanation is not forced by these phenomena. It seems quite possible, for instance, that reading habits may interfere with these tasks but not in the manner proposed. The likelihood of finding an error or locating a letter in a specific location may well reflect the ease one has in decomposing that portion of text into letter elements for consideration rather than reflecting whether or not visual information from such letters is normally attended to and used in reading.

In this brief review, we have attempted to show that although there are phenomena that are compatible with the notion that certain aspects of textual stimuli are being selectively ignored during reading, the evidence for this position is far from conclusive. In order to study the question more directly, methods are needed for indicating what aspects of the stimulus are being encountered as people are in the act of reading. This is extremely difficult to achieve, but one possible approach is described later.

Studies of Perception During Reading

A number of studies have been conducted that deal more directly with perception during reading. In this section, the results of these studies are examined to see whether they provide evidence that readers use different visual information under different contextual conditions; that is, evidence for top-down control over the functional stimulus in reading. First, however, it is necessary to consider some aspects of perception that might be influenced by contextual information.

It is obvious from the outset that the perception of meaning from text at any moment is influenced by the meaning of the earlier portions of the passage. We do not suppose that this generalization is in question. Rather, here we deal with only one aspect of perception: the question of the functional stimulus. Does contextual information influence what aspects of the textual stimulus are encountered and used during reading?

There are at least three ways in which such an influence might occur. First, contextual information may influence where the eyes are sent for fixations. Where the eyes are centered determines what visual information is potentially available for use in reading. The greatest visual detail is only available from the small region of text that happens to lie directly on and around the fovea. Visual acuity drops off rapidly in the more peripheral visual areas. Second, contextual information may influence the general size and location of the textual region attended to during a fixation. Although there are physiological limits on the level of detail available from different retinal areas, recent research has also demonstrated that attentional factors determine whether potentially available information is actually perceived. With the eyes centered at the same location, a subject is quite capable of attending to different visual regions, thus influencing the likelihood that visual patterns will be detected or used from these different regions (e.g., see Engel, 1976; Rayner, McConkie, & Ehrlich, 1978; Sperling & Melchner, 1978). Third, research by Neisser and Becklen (1975) indicates that narrowing the region within which visual information is used is probably not the only effect of

attention. Their results suggest that subjects can give attention to the same general area but respond to different aspects of the stimulus pattern presented there. Thus, it may be that people can attentionally select certain aspects of the stimulus within the general attended region, and ignore other aspects.

Our purpose here is to review studies in which relatively skilled readers are involved in the act of reading in order to determine whether contextual information is influencing the three different aspects of perception in reading just described. Essentially, this review consists of an attempt to evaluate evidence for top-down controls on perception in reading. The region being attended to during a fixation is considered first, then the basis for eye movement guidance, and finally the specific visual detail from the text that is used in reading. Definitive answers are not yet available for any of these questions, but some evidence is available on each issue.

The Text Region Attended

Eye movement records indicate, with some accuracy, the locations in the text where the eyes were centered during reading. However, this alone does not indicate what region of text was being perceived during each of these fixations or even whether the text was being seen at all. Vision researchers have studied the level of visual detail that can be perceived at different retinal locations and how this visual detail interacts with other factors such as the presence of other stimuli at specific locations in the visual field (e.g., see Bouma, 1973). This research can indicate what

visual information is potentially available from a passage when the eyes are centered at a specific location, but it does not indicate what region within this area is actually attended to during a fixation in reading, or whether the attended region varies from fixation to fixation. This requires research with subjects who are actually engaged in reading a passage. Such investigation is still in its infancy, but research techniques are now available which make it possible (e.g., see McConkie, Zola, Wolverton, & Burns, 1978; Reder, 1973).

In general, research conducted thus far seems to indicate that the region attended to during a fixation is influenced by the reading task itself. However, there is not yet clear evidence that the size or location of this region is varying from fixation to fixation on the basis of contextual factors.

During reading, one does not have the impression of getting meaning from the text on the lines above and below the line being read, although words on these lines are frequently within visual regions where they could be identified if desired. In several studies (e.g., Willows, 1974) extraneous textual materials have been placed between the lines of text, and evidence has been produced that such materials are perceived and influence what is retained from the text. This research has not yet been done using eye movement monitoring techniques to determine whether such extraneous materials are sometimes directly fixated. Also, the materials have frequently been printed in ways that might be expected to attract attention. For example, they have been printed in a different color and with different

spacing patterns from the rest of the text. Thus, it is still not clear whether, in normal reading, information is acquired from lines other that the one being read.

McConkie and Rayner (1976) demonstrated that skilled readers use little, if any, visual information more than four letter positions to the left of the fixation point (the letter on which the eyes are centered in the text) during a fixation in reading. Present research is being conducted in our laboratory to determine whether information is even picked up that far to the left of the fixation point. Bouma (1973) has shown that words can be identified when presented farther to the left than this. Thus we seem to have a clear example of attentional selectivity occurring during reading. Apparently the visual region attended to during fixations in reading lies primarily on and to the right of the center of vision. Whether this differs for Hebrew readers, who read from right to left, or whether it changes when the reader makes regressive (leftward) movements during reading are interesting questions needing study.

There is also some evidence that a region of text tends not to be given attention on two successive fixations. This is in contrast to Smith's (1971) suggestion that the perceptual span is wide enough to permit the same word to be seen on several fixations, thus contributing to accuracy of its identification. In one study (McConkie, Note 1) pairs of words were identified that differed in a single letter (for instance, leaks and leans). Sentences were written in which either word was appropriate (e.g., John did not store his tools in the garage because it ----- too much). College

students then read these sentences from a computer-controlled cathode-ray tube (CRT) as their eye movements were recorded. During each forward eye movement, the critical letter differentiating the two words was switched; that is, the word leaks was present during one fixation, the word leans during the next, leaks during the next, etc. Thus, the word was different on successive fixations. If the word in the critical location was identified on two fixations, some difficulty should have been encountered. The results indicated that the subjects were entirely unaware that any change was taking place in the display, and their eye movement records showed no evidence of disruption from the display changes; that is, there were no differences between change and no change conditions in mean fixation durations, saccade lengths, or number of regressive eye movements. Subjects could generally report what word they saw in the sentence. We tend to believe their reports because in the sentences where the critical word was not changing (one of the words was continuously present) the subjects were very accurate at selecting the word that was present. Thus, it seems likely that once a region of text has been perceived, or read, that region is not reconsidered during the next fixation even though it may lie well within the visual area in which identification would be possible.

If the text regions attended on successive fixations are discrete from one another, this would suggest that the variability typically present in the lengths of saccades during reading may be reflecting a similar variability in the size of the text regions being attended to during different fixations. Thus, the distance the eyes are sent for a saccade in

reading may reflect how far to the right of the fixation point "reading" was successful (McConkie, 1979; McConkie, Hogaboam, Wolverton, Zola, & Lucas, 1979). This speculation appears to be receiving some support from a series of studies presently being conducted by a member of our research group (Hogaboam, Note 2). In these studies, subjects read a passage from a CRT as their eye movements are being monitored. During occasional saccades the text is replaced with a line of X's. Thus, the text is gone when the eyes stop for the next fixation. When this happens, the subjects' task is to report the last few words they remember reading, to indicate anything they can say about the next word (e.g., its first letter or approximate length), and to guess what the next word might be. The results indicate that subject can sometimes report the word to which their eyes are being sent (about 30% of the time), but they very seldom report the word to the right of it. Thus, it appears that sometimes readers have enough information about the word to which their eyes are being sent for the next fixation to be able to identify it if needed, but most of the time this is not the case.

This then leads to the question that is of great interest and that cannot be answered at this time. Is the variability in the size of the region apparently attended to and interpreted during a fixation related to contextual variables? Investigating this question is one of the planned "next steps" in our research program, but no conclusive answer can be given at this time.

Where the Eyes are Sent

Speculations about the basis on which the mind decides where to send the eyes during reading have ranged over a wide area, from those suggesting little or no specific guidance (Bouma & deVoogd, 1974; Shebilske, 1975) to those suggesting that the eyes are sent precisely to locations based on where the most informative regions of text will be (Hochberg, 1970; Smith, 1971). Data presently being analyzed from a study we have conducted provide evidence that the eyes are being sent to rather specific locations, but the data provide no evidence concerning the basis for that guidance. As college students were reading from a CRT, the text was shifted on the screen two letter positions to the left or right during certain saccades. This caused the eyes to stop for the next fixation at a location two letter positions away from that point in the text where they normally would have stopped. The subjects reported that they had not been aware that the text had moved, but this manipulation had a substantial effect on their eye movement patterns. When the text was shifted to the left, causing the eyes to stop two letter positions farther along the line than they normally would have, a large number of short regressive movements of about two to three letter positions in length were produced. A similar shift to the right reduced the normal number of regressive movements by one-half and produced an increase in short forward saccades. Thus, the eyes seem to be sent to a rather specific location in the text during a saccade in reading; experimentally displacing that location by just two letter positions clearly affects the person's reading behavior.

There is also considerable evidence indicating that the eyes tend to be sent to some regions in text rather than others during reading (Levy-Schoen & O´Regan, 1979; Rayner, 1978). Rayner (1975) and Abrams and Zuber (1972) found a tendency for the eyes to avoid being centered in empty spaces, including the spaces between sentences. Rayner and McConkie (1976) reported a relation between the length of a word and the probability of fixating a letter in the word. O´Regan (1979) has demonstrated a tendency to send the eyes farther when the next word is a longer word and a tendency to skip the word the in one syntactic frame (but not in another). He also reported a greater tendency to fixate a particular region if it contained a three-letter verb than if it contained the word the. All these results point to the existence of some sort of control of eye movements in reading (though reading is still possible in the absence of this control, as demonstrated by Bouma & deVoogd, 1974). However, this line of research leaves much to be discovered about the rules on which this control is based, and even about the degree to which it is based on contextual versus visual information.

One reasonable possibility, stated most clearly by Hochberg (1970), is that in some way the mind avoids sending the eyes to regions where the language is highly predictable because such regions are relatively uninformative. Instead the eyes are sent to more informative regions. Thus the reader´s knowledge of the language and of the topic being discussed may be brought into play to aid perception by guiding the eyes in a manner that contributes to efficiency. O´Regan´s the-skipping effect could be seen as an example of this.

Zola (Note 3) has attempted to test this possibility in a recent study. He identified seven- or eight-letter nouns that could be highly constrained in passage contexts by single preceding seven- or eight-letter adjectives. For instance, in a paragraph concerning a movie theater, the word buttered can make it highly probable that the next word will be popcorn. Zola wrote 250 paragraphs, each containing one such target word, preceded immediately by its constraining word. These paragraphs, up to the target word, were given to 150 college students who indicated what the next few words would probably be. The target word was given by at least 85% of the subjects and for many paragraphs, by 100% of them. A second version of each passage was also prepared in which the constraining adjective was replaced by another adjective of equal length; for instance, buttered popcorn was replaced by adequate popcorn, optical illusion by curious illusion, etc. When given these paragraphs up to the target word, students guessed the next word less than 15% of the time. Thus, by the choice of an adjective in these paragraphs, the target noun could be highly constrained or left with considerably less constraint. In the high-constraint condition, the target noun had practically no information value.

Subjects then read 100 of these paragraphs while their eye movements were being recorded, and the data were analyzed to determine the frequency with which the target noun was directly fixated under high- and low-constraint conditions. Zola found that subjects made fixations on the target noun over 96% of the time regardless of the level of constraint. Thus, there was no observable tendency to skip the target noun when it was

almost completely specified by the context. Fixation durations on the target noun averaged about 16 msec. shorter in the high constraint condition, indicating that the language constraint was facilitating processing in some manner. In this study, there seemed to be no tendency for skilled readers to skip over a highly predictable word as they were reading. These results do not support the hypothesis of high-level control of eye movements based on language constraints.

Regressive eye movements have typically been believed to result from some confusion on the part of the reader, in which some part of the text read earlier was not correctly identified (Huey, 1908/1968). Thus, it has often been suggested that high-level processes detect the incompatibility resulting from earlier misreading, and that the eyes are then sent back to perform a reanalysis of the earlier text to correct the misreading. This would be an example of high-level processes controlling an aspect of perception. Carpenter and Just (1977; Just & Carpenter, in press) provide one example of indeterminacy in the text stimulating regressive movements. When the referent to a pronoun was ambiguous, the reader's eyes tended to regress to one of the possible referents, mentioned earlier, and the interpretation of the passage was then generally harmonious with that being taken as the referent of the pronoun. These researchers report that the eyes tended to go rather directly to one potential referent or the other, suggesting that the reader remembered rather precisely the physical location of the words, rather than a tendency for the eyes to scan the text in search of an appropriate referent. Thus it is not clear that the regression was

stimulated by a need to search for an appropriate referent; perhaps it simply reflected the referent chosen together with the fact that the choice was not entirely clear. The regression may have been the result of the referent choice rather than being involved in its cause. Clearly this interesting phenomenon needs further investigation.

In studies mentioned earlier, Hogaboam has also collected some data in which the text was masked and removed from the screen while the reader was making a particular regressive eye movement (say, the second regression on the eighth line of text). The subject then reported the last word read. Relatively few of these instances have been recorded thus far, but the data show a consistent pattern. The word that the subjects give is the last word fixated prior to the regression. Thus, the subjects have identified this word. The regression is not being stimulated by the eyes outrunning the mind and having to go back to some point where word identification faltered. In addition, in this study subjects often report the last several words read, although they are only required to report one. It is of interest that no instances have been observed where these reports show any of the kinds of confusions or misreadings that are typically suggested to be the stimulus for regressive eye movements. Research is continuing in the attempt to learn what the stimulus for regressive movements in reading is.

To date, our research, which admittedly is far from providing final answers on these questions, has not manifested data patterns that require the complex, high-level eye movement control based on language constraints that has been common in reading theories.

Attended Aspects of the Visual Stimulus During Reading

Given that the eyes are centered at a certain location for a fixation and that attention is given to a particular region of the text, the final question concerns whether language constraints influence what aspects of the text are used in reading. This is, of course, a very difficult question to study, particularly with subjects actually engaged in reading a passage, and it requires extensive research effort. However, a few initial observations can be made at this time.

One possibility that has been suggested, particularly by Goodman (1967), is that the reader anticipates the text about to be encountered and then only uses a minimal amount of visual detail to test these anticipations. This suggests that the text is in some sense known before the eyes are sent to it. If this were the case, we might expect that if the text were suddenly to go blank during an eye movement and the readers were asked what words were likely to come next, they would respond readily and with a fair degree of accuracy. In Hogaboam's study (Note 2), which used this procedure, subjects reported with great accuracy a word no farther to the right than that to which they were sending their eyes on that eye movement, and usually not that far. Frequent prompting and encouragement were required to get them to try to guess the next word, which was often the word to which the eyes were being sent. They felt very unsure, and in fact the accuracy of their guesses was quite poor. Thus, the data indicated an important distinction between the words that had been read, which the subjects reported with confidence and high accuracy, and those that lay

farther to the right, about which the subjects were reluctant to guess. The readers did not seem to have active, conscious hypotheses concerning the text that lay beyond the words that had been read, even when they had been or were about to be fixated. Although this is not a critical test of hypothesis and verification models of reading, and results place rather severe constraints on any such theory.

Another relevant observation comes from studies in which we have had subjects read sentences containing one of two words that differ by a single letter at a given word position (the leaks-leans example has been cited earlier). In these sentences, the discrimination between two alternative readings of the sentence depends on the accurate identification of a single letter. In many of the sentences, the discriminating letters are visually quite similar in shape (e.g., beans and bears). Yet subjects are very accurate in reporting what the sentences actually say. If subjects were basing their reading on only parts of the visual information from the words, it would seem likely that more misidentifications would be observed in the reading of this material. On the other hand, it may be that the perceptual system operates in a way that causes it to focus on the acquisition of exactly those letters that are so critical to making the discriminations between such possible alternative words. This possibility needs further study.

A final set of observations comes from a study by Zola (Note 3), previously mentioned, in which the degree of constraint of target nouns in short paragraphs was varied by manipulating the immediately preceding

adjective. There were other conditions in this study in which the target words were altered in various ways in order to determine whether such errors would be disruptive to reading. Four experimental conditions had spelling errors of differing severity. A control condition had no spelling errors. In the minimal-error condition, the fourth letter of the target noun (always a seven- or eight-letter word) was replaced by its most visually similar letter, as determined by visual similarity data collected earlier. Thus, the smallest possible change permitted by the English alphabet was made in the most redundant part of the word; certainly this is information not needed for identification of the word, especially under high-redundancy conditions (Pillsbury, 1897). Other error conditions were more severe. In the third condition, the fourth letter was replaced by its most visually dissimilar letter from the same category, where letters were categorized as either ascenders, descenders, or others. In the fourth condition, the fourth letter was replaced by its most similar letter, and the fifth letter was replaced by a letter from a different category. This error condition caused a small change in the external shape of the target word. And in the fifth condition, the initial, fourth, and final letters were replaced.

The study was done under the assumption that if a reader only attended to that part of the visual stimulus that was necessary to select among contextually allowable alternatives, then more visual information would be needed from the target word in the low-constraint condition than in the high-constraint condition. Under high-constraint conditions, relatively little visual information would be needed for word identification: perhaps

only word length and initial and final letters. If this assumption were correct, then subjects would not attend to other aspects of the visual stimulus; unneeded visual information would not be processed; and errors that did not violate the needed information would have no effect on reading. Thus, under lower visual constraint, more visual detail should be used in word identification, and less severe errors should cause difficulty in reading.

The view of perception in reading just described would suggest that only the most severe errors would affect reading under high-constraint conditions where the target word could usually be identified on the basis of the prior context alone; less severe errors would cause difficulty in the low-constraint condition; and the minimal-error condition would have no effect in either condition, since the level of visual detail being changed was probably not needed for word identification under either condition.

The task given to the subjects was simply to read the passages and prepare to answer comprehension questions about them. The subjects were told that errors had been put in the text, but that their task was to ignore the errors and simply read for understanding. Subjects were given practice trials in which they read several paragraphs that contained errors. Throughout the study, a comprehension test was administered after each block of six paragraphs. The questions never involved information stated in sentences containing the errors. Subjects were not asked to comment about the errors during the experiment. Thus an active effort was made to orient the subjects toward reading for retention and away from attending to the

errors. In fact, in each block of 72 lines, there were only 8 errors, 2 of these being the minimal type. Thus, errors were infrequent in the text.

The study involved 20 college students each reading 100 paragraphs, with each paragraph containing one target noun. Thus each subject read 10 paragraphs under each of the 10 conditions (2 levels of constraint by 5 levels of error). The eye movement data were examined in detail to determine whether the errors had an effect on fixation durations, saccade lengths, and frequency of regressive movements in the area of the error, as compared to the no-error control conditions.

The results do not appear to support the description of perception in reading given earlier. As already indicated, there was no tendency for subjects to fixate the target nouns less frequently in high- than low-constraint conditions or to differ in where they fixated the word. It was not the case that small errors affected reading only in the low constraint condition. Even the minimal errors seemed to have an effect on subjects' reading behavior, under both the high- and low-constraint conditions. There is no condition in which the high-constraint paragraphs showed no effect of errors, but the low-constraint condition did. Thus, it appears that under both extremely high- and low-constraint conditions, visual detail was being encountered and used in reading that an information-theoretic-related position would claim was not needed. More extreme errors caused greater disruption in the reading patterns, as might be expected, and subjects in the high-constraint conditions had an easier time dealing with severe errors than subjects in the low-constraint conditions. But it appears that under

even the highest constraint, the subjects were attending to a great deal of the visual detail of the target noun, at least frequently enough to produce mean differences in eye movement measures as compared to the no-error condition.

The results from Zola's study appear to be yielding data patterns that stand as a rather direct challenge to some common notions of top-down influences on the selection of visual information during reading. This study was specifically designed to provide the opportunity for contextual influences on the functional stimulus to be manifested in the data patterns. However, no evidence has been found that readers encounter more of the visual stimulus of a word when there is less contextual constraint on the word; that they use only a small amount of the visual information to verify their hypotheses concerning the word; or that they employ some sort of noticing order from gross to fine detail in the word that terminates when sufficient information has been garnered to permit word identification given the present context. Rather, it appears that readers are responding to most of the visual detail of the stimulus even under high language constraint conditions. Whether they are conscious of the presence of small errors that are affecting their reading is, of course, another question requiring further research.

Where is Contextual Facilitation?

The conclusion that seems to be emerging from the research already discussed is that, whereas it may be possible for people to use contextual information to help identify a word when the stimulus alone is insufficient,

under adequate stimulus conditions the stimulus is rather fully used. Efficiency is apparently not gained by circumventing visual analysis. In fact, relying heavily on visual information may be more efficient in normal reading than having to depend too much on contextual information for word identification. Recently, there have been suggestions that as children become better readers they depend more heavily on the visual information from the text, rather than contextual information (e.g., Perfetti & Roth, in press; Stanovich, in press).

Although the studies reviewed here call into question a common explanation for the effects of contextual constraint on reading, at the same time they further document the existence of such effects. The question still remains. How should we explain the facilitation that results from contextual constraint during reading? O'Regan (1979) has shown that under some conditions the eyes are sent farther when the next word is an article (undoubtedly more predictable) than when it is a verb. Wanat (1971) has found that subjects spend less time looking at more constrained regions of sentences. Zola (Note 2) has shown a shorter fixation on a word when it is more highly constrained by its context. How can we account for such instances of facilitation if they do not result from reduced perceptual analysis?

One alternative that appears tempting is provided by recent research on priming, which comes from studies dealing with semantic memory. This research indicates that preceding the presentation of a word with the presentation of a semantically related word reduces the time necessary to

make lexical decisions about it (Meyer & Schvaneveldt, 1971). In some way, the activation produced by one word selectively facilitates the processing of a second related word. Of particular interest is the report that the first word can have this effect even when it has been presented for such a short time that the subject cannot indicate what the word was and sometimes is not even aware that a word was presented; that is, the priming word was below perceptual threshold (Marcel & Patterson, 1978). Without the priming word even being identified in any normal sense, its meaning seems to have been perceived, and the arousal of that meaning seems to have had an influence on decisions about a semantically related word presented later. This research, if replicated, suggests that the perception of words, including gaining meaning from them, can be a very direct sort of activity and is not something that might benefit from becoming entangled in decisions about what visual information to respond to (and in what order) on the basis of contextual information.

This body of research on priming raises an alternative way of conceptualizing perception in reading that will likely attract some attention in the future. Is it possible that at the beginning of a fixation, all the words that lie in a retinal region within which sufficient visual clarity is available for their identification rapidly arouse their meanings in the brain? If this were the case, then attentional processes would need to be thought of as selecting from among spatially tagged semantic information, rather than from visual patterns. The primary task of attentional processes would not then be the analyses of visual information

in order to identify what word or words were on the page, but rather would be selecting from those potential meanings, which are rather directly provided, the particular ones that will next contribute to the construction of an understanding of the message of the text. From this view, contextual facilitation effects may aid in the arousal of those meanings through priming (Fischler & Bloom, 1979), and attentional selectivity would then be occurring with higher-level representations, rather than at the level of visual information. Exploring this possibility requires experimental techniques that will indicate whether readers are in some way responding to the meanings of words that lie outside the region being directly attended to during fixations.

We have one further observation to make that may place some constraints on this way of conceptualizing perception during reading. We have constructed sentences and short paragraphs in which either of two words could occupy particular word positions. These two words differed by only a single letter. As subjects read the materials, one of the words was present for the first 80 or 100 msec of each fixation. The text was then disrupted briefly by presenting a 20-msec mask (a line of X's) or by shifting the entire line one letter position to the right and then returning it to its original position. When the original text returned, a letter had been changed in the target word, which of course resulted in a different word occupying that location for the rest of the fixation. After reading these texts, the subjects were asked questions designed to reveal which word they read in the sentence and were then asked whether they saw more than one

word. In this pilot work, sometimes a subject reported only the first word presented, sometimes only the second word, and sometimes reported having seen both words. Thus, in some instances, the subjects seemed to have employed the meaning from that word early during the fixation and sometimes, only later during the fixation. It does not seem to be true that the meanings of all words are settled upon during the initial few milliseconds of a fixation, nor that a change in meaning at some point in the visual field will be detected.

The preliminary results from this pilot study seem to support the position that information from different regions of the visual field is used in reading at different times during the fixation. Thus, if meanings are aroused rapidly at the beginning of a fixation, as the priming literature might suggest, it still seems that the employing of these meanings for the purpose of understanding the text is an activity that takes place over the time of the fixation in some sort of systematic fashion. In addition, these results suggest that, given this way of thinking about perception in reading, one would have to conclude that meanings can be masked and changed during a fixation without conscious awareness that such a change has occurred.

Whether or not a priming-based theory of this sort can account for contextual facilitation during normal reading is a question that will require considerable thought and research ingenuity. Perhaps most important at the present time is the need for more careful studies that document and describe the effects of contextual constraints during reading. Only by

having a number of well-established observations about these effects will we be in a position to select among alternative possible explanations.

Conclusion

In this paper we have attempted to review the evidence available to support the notion that the visual information used in reading is a function of the contextual information available. Results from studies of language identification in noise and of word identification from tachistoscopic presentation clearly indicate that contextual information can be used to facilitate word identification under inadequate stimulus conditions. However, these results do not provide strong evidence that such an interaction is occurring during normal reading. Other forms of evidence using tasks more similar to reading (proofreading errors and errors in reading aloud), though compatible with this position, also do not require it.

Three aspects of perception were identified that might be affected by contextual information: where the eyes are sent, the visual region attended to, and the visual information within that region that is used for reading. The studies conducted to date that investigate perception during reading are not definitive on these issues. However, there currently appears to be no clear evidence that the contextual information environment exerts control over what visual information is used in reading, that is, over the functional stimulus. In fact, subjects appear to be responding to considerable visual detail of words that are almost completely constrained by their prior context. From present evidence, it seems quite possible that

contextual facilitation is not achieved by reducing the amount of visual information a reader acquires from individual words.

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